The Body-Scale Relationship for Adult Sockeye *(Oncorhynchus nerka)*, Pink *(O. gorbuscha)*, Chum Salmon *(O. keta)*, and Chinook Salmon *(O. tshawytscha)*

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THE BODY-SCALE RELATIONSHIP FOR ADULT SOCKEYE (*Oncorhynchus nerka*), PINK (*O. gorbuscha*), CHUM SALMON (*O. keta*), AND CHINOOK SALMON (*O. tshawytscha*)

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ABSTRACT

Bilton, H. T. 1985. The body-scale relationship for adult sockeye (*Oncorhynchus nerka*), pink (*O. gorbuscha*), chum salmon (*O. keta*) and chinook salmon (*O. tshawytscha*). Can. Tech. Rep. Fish. Aquat. Sci. 1353: 19 p.

The body-scale relationship for adult sockeye, pink, chum and chinook salmon of different ages, brood years and locations was examined. Generally, the correlation coefficients between fish length and total scale radius or total number of circuli for each age of each species were low, ranging from a low of 0.191 for age 1.3 sockeye to a high of 0.606 for age 0.3 chinook. Even when ages were combined, the correlation coefficients for sockeye, pink, and chum salmon remained low, ranging from a low of 0.386 for pinks (length versus number of circuli) to a high of 0.571 for chums (length versus circuli). Only the correlation coefficients for chinook salmon were moderately high at 0.857 and 0.794 for length and scale radius, and length and circulus number, respectively. Hence, with exception of the chinooks, only very gross estimates of prior growth of the other three species can be made from examination of their scales. It is speculated that the reasons for the low correlations may be associated with the fact that scale samples from adult sockeye, pink, and chum salmon caught in the net fishery near river mouths had begun resorption of their scales with the beginning of maturity. The chinook samples on the other hand, were mainly collected from troll caught fish sometime prior to the onset of the process of maturity, hence resorption of their scales probably had not begun to occur. This would account for the higher correlation coefficients. The lines of best fit describing the relationships for sockeye and pink salmon tended to change from one brood year to the next. Similar comparisons could not be made for chinook and chum salmon as only fish from one brood year were examined. Analysis of variance testing for differences in the regression lines for sockeye, pink and chum salmon from different locations indicated, in some cases, significant differences among fish from different locations. Such differences must be related to either genetic or environmental factors, or a combination of both.

RÉSUMÉ

Bilton, H. T. 1985. The body-scale relationship for adult sockeye (Oncorhynchus nerka), pink (O. gorbuscha), chum salmon (O. keta) and chinook salmon (O. tshawytscha). Can. Tech. Rep. Fish. Aquat. Sci. 1353: 19 p.

L'auteur a étudié la relation entre les écailles et la longueur du poisson chez des saumons rouges, roses, kétas et quinnats de différents âges, générations et endroits. De façon générale, les coefficients de corrélation entre la longueur du poisson et le rayon total de l'écaille ou le nombre total d'anneaux pour chaque âge de chaque espèce étaient faibles, variant de 0.191 pour le saumon quinnat d'âge 1.3 à 0.606 pour le saumon quinnat d'âge 0.3. Même lorsqu'on regroupait les âges, les coefficients de corrélation restaient bas pour les saumons rouge, rose et kéta, allant de 0.386 pour les saumons roses (longueur par rapport au nombre d'anneaux) à 0.571 pour les saumons kétas (longueur par rapport aux anneaux). Seuls les coefficients de corrélation pour le saumon quinnat étaient assez élevés, soit 0.857 pour la longueur comparée au rayon de l'écaille et 0.794 pour la longueur comparé au nombre d'anneaux. Par conséquent, à l'exception des saumons quinnats, l'auteur n'a pu faire à partir de l'examen des écailles qu'une évaluation très grossière de la croissance chez les trois autres espèces. Il émet l'hypothèse que les faibles corrélations peuvent être dues au fait que pour les écailles des saumons rouges, roses et kétas adultes capturés au filet près de l'embouchure des cours d'eau, il ait pu y avoir un début de résorption coïncidant avec le début de la maturité. Par contre, les échantillons d'écailles de saumons quinnats ont été prélevés chez des poissons capturés à la ligne trainante avant le début du processus de maturité; il en est donc probable que dans ce cas-là, les écailles n'avaient pas commencé à se résorber. Cela expliquerait pourquoi les coefficients de corrélation sont plus élevés. Les droits de meilleur ajustement décrivant les relations chez le saumon rouge et le saumon rose avaient tendance à changer d'une génération à l'autre. Comme l'auteur n'a examiné que des saumons quinnats et kétas d'une seule génération, il n'a pu faire de comparaisons semblables pour ces espèces. Les analyses de variance faites pour expliquer les différences dans les droits de régression pour les saumons rouges, roses et kétas provenant de différents endroits ont indiqué, dans certains cas, des différences significatives chez les poissons provenant d'endroits différents. Ces différences doivent être liées soit à des facteurs génétiques ou environnementaux, ou aux daux à la fois.

INTRODUCTION

Growth of adult pink and chum salmon stocks has been estimated from measurement of distances between the annuli on the scales, and from the last annulus to the scale margin (Ricker 1964). For adult salmon it is assumed there is a positive straight-line relationship between scale size and fish length.

The purpose of this report is to indicate the correlation and to provide regression equations describing the body-scale relationship in terms of both number of circuli and scale radius, of four salmon species from several stocks and brood years.

METHODS AND MATERIALS

Data for 674 sockeye, 532 pink, 400 chum and 200 chinook salmon sampled from the commercial net and troll fisheries along the British Columbia and Alaskan coasts in several years were used in this study. The number used by species, location, brood year and age are shown below.

Species	Location	Brood year	Year sampled	Age[1]	Number samples
Sockeye	Rivers Inlet (Net fishery)	1961	1965	1.2	50
		1961	1966	1.3	50
		1962	1966	1.2	50
		1962	1967	1.3	50
		1963	1967	1.2	50
		1963	1968	1.3	50
	Skeena River (Net fishery)	1961	1965	1.2	50
		1961	1966	1.3	50
		1962	1966	1.2	50
		1962	1967	1.3	50
		1963	1967	1.2	50
		1963	1968	1.3	50
	Wood River Alaska (Net fishery)	1961	1965	1.2	50
		1961	1966	1.3	50

Table cont'd

Species	Location	Brood year	Year sampled	Age[1]	Number samples
Pink	Bella Coola	1959	1961	0.1	50
	(Net fishery)	1960	1962	0.1	50
		1961	1963	0.1	50
		1964	1966	0.1	50
	Fraser River	1955	1957	0.1	50
	(Net fishery)	1961	1963	0.1	32
		1965	1967	0.1	50
	Skeena River	1961	1963	0.1	50
	(Net fishery)	1964	1966	0.1	50
		1965	1967	0.1	50
	Kodiak	1964	1966	0.1	50
	(Net fishery)				
Chum	Bella Coola	1959	1962	0.2	50
	(Net fishery)	1959	1963	0.3	50
		1963	1966	0.2	50
		1963	1967	0.3	50
	Johnstone Strait	1963	1966	0.2	50
	(Net fishery)	1963	1967	0.3	50
	Fraser River	1959	1962	0.2	50
	(Net fishery)	1959	1963	0.3	50
Chinook	General	1963	1966	0.2	100
	(Troll fishery)	1963	1967	0.3	100

Each fish was measured for hypural length in millimeters (the distance between the posterior orbit at the eye and the end of the hypural plate). The preferred scale or a scale from the preferred area (see INPFC Annual Report for 1955) was removed from each fish. In the laboratory, impressions of scales were made in acetate plastic cards, using the method described by Clutter and Whitesel (1956). Scale impressions were then examined under a Leitz-Prado, 123, microprojector. Images of the scale impressions were projected with a magnification of 100 times onto sheets of graph paper divided into millimeter squares. Each scale impression was oriented so that the longest axis of the image lay along the lines of the graph paper, and the center of the scale focus was at the edge. The outer edges of the images of each circulus from the focus to the edge of the scale were then marked on the graph paper, as were all annuli. The age of each fish was recorded.

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[1]The European system of age designation (Koo 1962) is used in this report. The first digit indicates the number of annuli formed in fresh water and the second digit the number of annuli formed while the fish were in the ocean.

Correlation coefficients and lines of best fit describing the relationship of fish length with total scale radius and total number of circuli were calculated for each of the four species by location, by age and brood year. Also, an analysis of variance was completed which compared the regressions (lines of best fit) among sockeye from three locations, originating from the same brood year, among pink salmon from three locations, originating from the same brood year, and among chum salmon from two locations originating from the same brood year.

RESULTS

SOCKEYE

The correlation coefficients and the slopes and intercepts of regression lines describing the relationships between fish length with total scale radius and total number of circuli by location, brood year and age are given in Tables 1 and 2. Within age groups the correlation coefficients between length and scale radius or number of circuli were all low. The overall averages of the correlation coefficients by age for all locations and brood years combined were as follows:

Age	$\bar{x}$ r value scale radius	r^2 x 100%	$\bar{x}$ r value number circuli	r^2 x 100%
1.2	0.321	10.3	0.220	4.8
1.3	0.358	12.8	0.191	3.6
1.2 and 1.3	0.552	30.5	0.536	28.7

For both ages there was a higher correlation between length and scale radius than with number of circuli. In neither case, were the r^2x100% values high, indicating that most of the variability in either scale radius or in total circuli was not associated with length of fish, but was related to other factors not understood. When ages were combined the overall averages of the correlation coefficients (r) were considerably higher than when ages were considered separately (the higher values of r were due to a wider range in size when ages were combined). However, even then, the values were not high. Only from 29-30% of the variability (r^2x100%) in scale radius and number of circuli could be accounted for by the effect of fish length. There was little difference between the average correlation coefficients for length with radius or with circulus number.

For fish of the same age from each location there were considerable differences between brood years in both the slopes and intercepts of the regression lines for length and scale radius and total circuli. However, when ages of fish from each location were combined the differences between brood years were reduced. However, the lines of best fit tended to change from one brood year to the next.

Results of analyses of variance, testing for differences in the slopes and intercepts of regression lines for fish length and total scale radius, and total circulus number for sockeye (for age 1.2 and 1.3 fish combined, from the 1961 brood year) from the three locations (Rivers Inlet, Skeena River and Wood River) indicate that the slopes did not differ significantly but the intercepts were significantly different (Table 3). Examination of the data indicate the Rivers Inlet sockeye had a higher number of circuli per unit increase in fish length than the Wood River or Skeena River sockeye. On the other hand, Skeena River sockeye had a smaller scale radius per unit increase in fish length than the Rivers Inlet or Wood River sockeye.

The regression formula describing these relationships for sockeye from the three locations were as follows:

	Body length - scale radius	Body length - circulus number
Rivers Inlet	$Y = 19.82 + 0.60\ X$	$Y = 16.59 + 0.15\ X$
Skeena R.	$Y = -11.28 + 0.61\ X$	$Y = 1.47 + 0.16\ X$
Wood R.	$Y = 41.79 + 0.58\ X$	$Y = -3.59 + 0.18\ X$

PINK

The correlation coefficients, and the slopes and intercepts of regression lines describing the relationships between fish length with total scale radius and total number of circuli by location and brood year are given in Tables 4 and 5. The correlation coefficients were all low. For length with scale radius they ranged between 0.083 and 0.672 with an overall average of the values of 0.424 ($r^2 \times 100\% = 18.0\%$). For length with total circuli they ranged between 0.000 and 0.570 with an overall value of 0.386 ($r^2 \times 100\% = 14.9\%$). Hence only a small part of the variability in both cases could be accounted for by the effect of fish length.

For fish from each location there were considerable differences between brood years in the slopes and intercepts of the regression lines for length and scale radius and total circuli. Hence, the lines of best fit tended to change from one brood year to the next.

Analysis of variance, testing for differences in the slopes and intercepts of regression lines for fish length - total scale radius/total circuli relationships for pink salmon (age 0.1 fish from the 1964 brood year) from three locations (Fraser River, Bella Coola and Kodiak) indicate: (a) with scale radius no significant differences in either the slopes or intercepts of the lines; (b) with total circuli, no significant difference in the slopes of the lines, but significant difference in their intercepts (Table 6). Examination of the data indicates Kodiak Alaska pinks had fewer circuli per unit increase of fish length than either the Bella Coola or Fraser River pinks. Hbwever, the scale radius per unit increase of fish length was the same for pinks from the three areas.

The regression formulae describing these relationships for pinks from the three locations were as follows:

	Body length - scale radius	Body length - circulus number
Fraser R.	$Y = 68.99 + 0.26\ X$	$Y = 37.60 + 0.02\ X$
Bella Coola	$Y = 14.27 + 0.38\ X$	$Y = 26.65 + 0.05\ X$
Kodiak	$Y = 34.27 + 0.32\ X$	$Y = 13.19 + 0.05\ X$

CHUM

The correlation coefficients and the slopes and intercepts of regression lines describing the relationships between fish length with total scale radius and total number of circuli by location and age are given in Tables 7 and 8. Within age groups the correlation coefficients between length and scale radius or number of circuli were all low. The overall averages of the correlation coefficients by age and locations were as follows:

Age	$\bar{x}$ r value scale radius	r^2 x 100%	$\bar{x}$ r value number circuli	r^2 x 100%
0.2	0.330	10.9	0.423	17.9
0.3	0.418	17.5	0.390	15.2
0.2 & 0.3	0.489	23.9	0.571	32.6

For the age 0.2 fish there was a higher correlation between fish length and circulus number than with scale radius. The opposite was the case

for age 0.3 fish. However, in neither case were the r^2 x 100% values high, indicating only from 11 to 18% of the variability could be accounted for by the effect of fish length. When ages were combined the overall averages were considerably higher (probably due to a wider range in size when ages were combined) than when ages were considered separately. Even so, they were not high, only 24-33% of the variability could be accounted for by the effect of fish size.

Results of analysis of variance, testing for differences in the slopes and intercepts of regression lines for fish length and total scale radius, and total circulus number for chums (for age 0.2 and 0.3 fish combined from the 1963 brood year) from the two locations indicated that neither the slopes nor the intercepts differed significantly (Table 9) for either circulus number or scale radius on fish length.

The regression formulae describing these relationships for chums from the two British Columbia locations were as follows:

	Body length - scale radius	Body length - circulus number
Bella Coola	Y = 58.45 + 0.44 X	Y = 8.16 + 0.12 X
Johnstone St.	Y = 77.53 + 0.40 X	Y = 0.67 + 0.13 X

CHINOOK

Correlation coefficients, the slopes and intercepts of regression lines describing the relationships between fish length and total scale radius, and total circulus number by age for fish from the 1963 brood year are given in Tables 10 and 11. Within each age group the total scale radius was more closely correlated to fish length than was total number of circuli (Tables 10 and 11). However, in both cases the value of the correlation coefficients were moderate. When both age groups were combined the correlation coefficients for length with total scale radius and total circuli were even higher (r=0.857 and 0.794, respectively, Tables 10 and 11).

DISCUSSION

The correlation between length and scale growth both in terms of number of circuli and scale radius was low in sockeye, pink and chum and moderate for chinook salmon when ages were considered separately. Even when ages were combined, the correlation coefficients were low among the sockeye, pink and chum salmon. There were moderately high r values for the chinooks.

Hence, chinook body length was more highly correlated with scale radius and circulus number than was the case for the other three species. The reason for this is not known. Scales for all four species were removed from the preferred area from each fish, thus the effect of variability that could arise from sampling from different body areas was essentially removed. Perhaps, the reason for the higher correlation coefficients for the chinooks was due more to when the fish were caught and sampled than to anything else. Virtually all of the chinook samples in this study were taken from fish caught in the troll fishery. These fish, in many cases, were taken a considerable time before maturity, prior to their migration to spawn in freshwater, and as a result their scales may have not begun the process of resorption (it is well known that salmon resorb their scales as they mature, resulting in a decrease both in scale radius and circuli number). On the other hand, the three other species were caught by the net fishery on their spawning migration near river mouths and may have begun the resorption of scale material as they began to mature. This would account for the low correlations observed for these three species. Perhaps if fish had been caught earlier, before the onset of maturation the correlations would have been as high as the chinooks or even higher. As a result, back calculation of growth of sockeye, pink and chum salmon from scales of adult fish taken in the fishery would provide only very gross estimates of size at earlier ages. On the other hand, estimates of growth derived from scales of troll caught chinooks would tend to be more accurate.

Comparison of correlation coefficients derived for sockeye, chum and chinook salmon of different ages indicated the correlation coefficients for fish length and scale radius tended to be higher among the older chum and sockeye (age 0.3 and 1.3, respectively) and among the younger chinook salmon (age 0.2). The reverse was the case for correlation coefficients for fish length and circulus number where correlations were higher among younger chum and sockeye and older chinook salmon. Why this occurred is not understood. Perhaps this also was somehow associated with maturity of the fish at time of capture.

The lines of best fit describing the relationships for sockeye and pink salmon tended to change from one brood year to another. This may reflect annual differences either in when the samples were taken, or in the rates of maturity. As samples of fish from only one brood year of chinook and chum salmon were used, similar comparisons could not be made for these species.

Analysis of variance testing for differences in the regression lines for sockeye, chum and pink salmon from different locations indicated there were significant differences in some cases among fish from different locations. Rivers Inlet sockeye laid-down more circuli per unit increase in fish length than did either the Skeena or Wood Rivers fish. On the other hand, Skeena River sockeye had a smaller increase in scale radius per unit increase in length than did fish from the other two locations. Pink salmon from Wood River Alaska, formed fewer circuli per unit increase in body length than did those from the two British Columbia locations. However, there was no

difference in scale radius per unit increase in length among fish from the three locations. As a result, scales of pinks from Alaska would have more widely spaced circuli than scales from the two B.C. locations. A difference was not observed in the lines of best fit among chums from the two B.C. locations. In summary, such differences in scale formation for fish from different locations must be related to either genetic or environmental factors, or a combination of both. It would be both useful and interesting to determine experimentally how much influence both these factors have on scale formation.

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Table 1. The correlation coefficient (r) and time of best fit describing the relationship between fish length and scale radius for sockeye salmon of different ages from several brood years and three locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length (x): P[1]	Hypural length (x): $\bar{x}$ (mm)	Hypural length (x): SD	Scale radius (Y): $\bar{x}$ (mm)	Scale radius (Y): SD
Scale radius (y) and fish length (x)	Rivers Inlet	1961	1.2	y= 74.128+0.473x	x=255.755+0.658y	50	0.558	<.001	442.1	21.7	283.3	18.4
			1.3	y=114.434+0.423x	x=342.879+0.526y	50	0.473	<.001	519.2	28.7	335.1	25.8
			1.2 & 1.3	y= 19.821+0.602x	x=142.719+1.093y	100	0.811	<.001	480.6	46.4	309.2	34.4
	Rivers Inlet	1962	1.2	y=190.090+0.207x	x=355.544+0.330y	50	0.260	NS	448.9	27.5	283.0	21.7
			1.3	y=125.675+0.452x	x=213.845+0.825y	50	0.610	<.001	506.3	36.7	354.5	27.2
			1.2 & 1.3	y=-41.838+0.755x	x=239.193+0.748y	100	0.751	<.001	477.6	43.3	318.8	43.5
	Rivers Inlet	1963	1.2	y=103.674+0.435x	x=215.462+0.742y	50	0.568	<.001	431.7	25.8	291.5	19.8
			1.3	y= 48.980+0.568x	x=410.314+0.308y	50	0.418	<.01	515.6	21.5	341.8	29.2
			1.2 & 1.3	y= 44.774+0.574x	x=138.794+1.067y	100	0.782	<.001	473.7	46.3	316.7	35.4
	Skeena River	1961	1.2	y=211.608+0.145x	x=351.193+0.526y	24	0.276	NS	500.7	26.7	284.2	14.0
			1.3	y= 61.782+0.722x	x=400.907+0.382y	50	0.525	<.001	521.0	19.9	314.4	27.3
			1.2 & 1.3	y=-11.280+0.614x	x=371.279+0.470y	74	0.537	<.001	514.4	24.4	304.6	27.9
	Skeena River	1962	1.2	y=163.263+0.247x	x=375.584+0.314y	50	0.289	<.05	470.9	18.2	279.6	15.5
			1.3	y= 53.67 +0.525x	x=373.260+0.457y	50	0.489	<.001	523.3	19.0	328.4	20.3
			1.2 & 1.3	y=-69.864+0.752x	x=240.874+0.843y	100	0.796	<.001	497.1	32.2	303.9	30.4
	Skeena River	1963	1.2	y=125.018+0.366x	x=240.763+0.767y	50	0.530	<.001	468.0	30.4	296.3	21.0
			1.3	y=158.282+0.340x	x=418.480+0.313y	50	0.325	<.02	523.8	21.7	336.4	22.6
			1.2 & 1.3	y= 74.334+0.489x	x=201.653+0.927y	100	0.673	<.001	494.9	40.7	316.3	29.6
	Wood River	1961	1.2	y=151.916+0.321x	x=289.192+0.515y	50	0.406	<.001	440.2	23.6	293.2	18.6
			1.3	y= 78.862+0.509x	x=398.446+0.293y	50	0.386	<.01	498.4	21.6	331.0	28.4
			1.2 & 1.3	y= 41.795+0.580x	x=257.710+0.671y	100	0.623	<.001	467.8	35.9	313.1	33.3

[1]P is the significance level for r.

Table 2. The correlation coefficient (r) and line of best fit describing the relationship between fish length and number of circuli for sockeye salmon of different age from several brood years and three locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length: P[1]	Hypural length (mm): $\bar{x}$	Hypural length (mm): SD	Number circuli: $\bar{x}$	Number circuli: SD
Number circuli (y) and fish length (x)	Rivers Inlet	1961	1.2	y= 56.461+0.056x	x=319.986+1.504y	50	0.289	<.05	442.1	21.7	81.2	4.2
			1.3	y =72.281+0.046x	x=438.923+0.834y	50	0.197	NS	519.2	28.7	96.2	6.8
			1.2 & 1.3	y= 16.596+0.150x	x=157.355+3.645y	100	0.739	<.001	480.6	46.4	88.7	9.4
	Rivers Inlet	1962	1.2	y= 70.640+0.018x	x=405.015+0.558y	50	0.100	NS	448.9	27.5	78.7	5.0
			1.3	y= 47.932+0.096x	x=263.542+2.515y	50	0.492	<.001	506.3	36.7	96.5	7.2
			1.2 & 1.3	y= 4.043+0.175x	x=233.416+2.787y	100	0.700	<.001	477.6	43.3	87.6	10.9
	Rivers Inlet	1963	1.2	y= 45.051+0.086x	x=289.898+1.726y	50	0.386	<.01	431.7	25.8	82.2	5.8
			1.3	y= 94.064+0.010x	x=501.610+0.141y	50	0.031	NS	515.6	21.5	99.2	5.9
			1.2 & 1.3	y= 11.598+0.167x	x=141.708+3.660y	100	0.783	<.001	473.7	48.3	90.7	10.3
	Skeena River	1961	1.2	y= 41.737+0.072x	x=378.696+1.569y	24	0.336	NS	500.7	26.7	77.8	5.7
			1.3	y= 37.600+0.100x	x=410.759+1.229y	50	0.350	<.02	521.0	19.9	89.7	5.7
			1.2 & 1.3	y= 1.471+0.164x	x=383.874+1.521y	74	0.500	<.001	514.4	24.4	85.8	8.0
	Skeena River	1962	1.2	y= 47.769+0.056x	x=401.525+0.936y	50	0.228	NS	470.9	18.2	74.1	4.5
			1.3	y= 68.761+0.036x	x=483.988+0.449y	50	0.126	NS	523.3	19.0	87.6	5.4
			1.2 & 1.3	y=-12.091+0.187x	x=274.081+2.758y	100	0.718	<.001	497.1	32.2	80.9	8.4
	Skeena River	1963	1.2	y= 58.131+0.041x	x=313.246+2.002y	50	0.538	<.001	468.0	30.4	77.3	4.4
			1.3	y= 53.510+0.072x	x=433.909+0.985y	50	0.264	NS	523.8	21.7	91.2	5.9
			1.2 & 1.3	y= 6.910+0.156x	x=237.107+3.071y	100	0.693	<.001	494.9	40.7	84.3	8.7
	Wood River	1961	1.2	y= 64.336+0.020x	x=403.923+0.496y	50	0.100	NS	440.2	23.6	73.1	4.8
			1.3	y= 50.942+0.075x	x=413.684+0.928y	50	0.264	NS	495.4	21.6	88.1	6.2
			1.2 & 1.3	y= -3.589+0.180x	x=253.139+2.663y	100	0.692	<.001	467.8	35.9	80.6	9.3

[1] P is the significance level for r.

Table 3. Analyses of variance, testing for differences in the slopes and elevations of regression lines of length-radius relationship, length-circulus relationship for 1961 brood-year sockeye (age-1.2, return year 1965; -1.3 in return year 1966) from the Skeena River, Rivers Inlet and Wood River, Alaska.

		Sum of squares	d.f.	Mean squares	F ratio
Length-radius	Slope=0	136,676.65	1	136,676.65	248.040 xxxx
	Slopes equal	53.24	2	26.62	0.048 ns
	Elevations equal	29,402.56	2	14701.28	26.679 xxxx
	Residual	147674.85	268	551.02	
Length-circuli	Slope=0	10,051.44	1	10,051.44	224.765 xxxx
	Slopes equal	72.69	2	36.34	0.812 ns
	Elevations equal	2,273.83	2	1,136.92	25.423 xxxx
	Residual	11,984.49	268	44.72	

xxxx=significant at 0.5% level; ns=not significant at 5% level.

Table 4. The correlation coefficient (r) and line of best fit describing the relationship between fish length and scale radius for pink salmon of the same age from several brood-years and three locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length (mm): P[1]	Hypural length (mm): $\bar{x}$	Hypural length (mm): SD	Scale radius (mm): $\bar{x}$	Scale radius (mm): SD
Scale radius (y) and fish length (x)	Bella Coola	1959	0.1	y= 41.966+0.314x	x=365.710+0.559y	50	0.419	<.01	472.0	25.8	190.2	19.3
		1960	0.1	y= 98.571+0.169x	x=248.211+0.992y	50	0.409	<.01	415.7	44.3	168.8	18.3
		1961	0.1	y= 62.386+0.254x	x=336.477+0.648y	50	0.404	<.01	451.2	31.8	176.9	19.9
		1964	0.1	y= 14.266+0.378x	x=231.690+1.194y	50	0.672	<.001	453.3	41.8	185.6	23.5
	Fraser River	1955	0.1	y= 3.469+0.402x	x=305.031+0.850y	50	0.584	<.001	467.8	32.1	191.5	22.1
		1961	0.1	y=159.948+0.054x	x=435.842+0.136y	50	0.083	NS	460.9	31.1	184.8	19.7
		1965	0.1	y= 68.893+0.260x	x=350.059+0.714y	50	0.431	<.01	490.3	34.9	196.4	21.1
	Skeena River	1961	0.1	y= 78.029+0.221x	x=431.786+0.124y	50	0.164	NS	453.9	35.5	178.3	47.4
		1964	0.1	y= 45.457+0.304x	x=307.780+0.750y	50	0.477	<.001	442.8	24.4	180.1	15.6
		1965	0.1	y= 42.009+0.315x	x=262.367+1.042y	50	0.573	<.001	455.7	25.4	185.6	13.9
	Kodiak	1964	0.1	y= 34.268+0.318x	x=328.901+0.621y	50	0.445	<.01	436.5	20.1	179.3	42.8

[1]P is the significance level for r.

Table 5. The correlation coefficient (r) and line of best fit describing the relationship between fish length and number of circuli for pink salmon of the same age from several brood years and three locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length: P[1]	Hypural length: $\bar{x}$ (mm)	Hypural length: SD	Number circuli: $\bar{x}$	Number circuli: SD
Number circuli (y) and fish length (x)	Bella Coola	1959	0.1	y= 27.134+0.045x	x=327.642+2.971y	50	0.367	<.02	472.0	25.8	48.3	3.2
		1960	0.1	y= 29.840+0.037x	x=147.797+5.924y	50	0.472	<.001	415.7	44.3	45.2	3.5
		1961	0.1	y= 25.574+0.049x	x=283.195+3.677y	50	0.427	<.01	451.2	31.8	45.7	3.7
		1964	0.1	y= 26.654+0.047x	x=190.883+5.472y	50	0.506	<.001	453.3	41.8	48.0	3.9
	Fraser River	1955	0.1	y= 19.510+0.060x	x=210.385+5.411y	50	0.570	<.001	467.8	32.1	47.6	3.3
		1961	0.1	y= 48.581-0.002x	x=468.224-0.152y	50	0.000	NS	460.9	31.1	47.7	3.9
		1965	0.1	y= 37.605+0.021x	x=414.578+1.580y	50	0.184	NS	490.3	34.9	47.9	4.1
	Skeena River	1961	0.1	y= 30.463+0.030x	x=308.833+3.291y	50	0.313	<.05	453.9	35.5	44.1	3.4
		1964	0.1	y= 22.501+0.049x	x=232.537+4.758y	50	0.483	<.001	442.8	24.4	44.2	2.5
		1965	0.1	y= 28.475+0.036x	x=273.149+4.068y	50	0.383	<.01	455.7	25.4	44.9	2.4
	Kodiak	1964	0.1	y= 13.188+0.054x	x=237.943+5.402y	50	0.544	<.001	436.5	20.1	36.8	2.0

[1] P is the significance level for r.

Table 6. Analyses of variance, testing for differences in the slopes and elevation of regression lines of length-radius relationship, length-circulus relationship of pink salmon from the Fraser River (1965 brood year), Bella Coola and Kodiak, Alaska (1964 brood year).

		Sum of squares	d.f.	Mean squares	F ratio
Length-radius	Slope=0	18,229.91	1	18,229.91	63.174 xxxx
	Slopes equal	500.87	2	250.43	0.867 ns
	Elevations equal	930.57	2	465.29	1.612 ns
	Residual	41,553.02	144	288.56	
Length-circuli	Slope=0	254.81	1	254.81	24.238 xxxx
	Slopes equal	28.88	2	14.44	1.373 ns
	Elevations equal	1,624.54	2	812.27	77.265 xxxx
	Residual	1,513.84	144	10.51	

xxxx=significant at 0.5% level; ns=not significant at 5% level.

Table 7. The correlation coefficient (r) and line of best fit describing the relationship between fish length and scale radius for chum salmon of different ages from the brood year and two locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length (mm): P[1]	Hypural length (mm): $\bar{x}$	Hypural length (mm): SD	Scale radius (mm): $\bar{x}$	Scale radius (mm): SD
Scale radius (y) and fish length (x)	Bella Coola	1963	0.2	y=164.591+0.240x	x=429.026+0.522y	50	0.353	<.02	588.7	35.8	305.9	24.3
			0.3	y= 56.400+0.451x	x=309.518+0.924y	50	0.645	<.001	620.0	36.7	338.0	25.6
			0.2 & 0.3	y= 58.452+0.437x	x=393.883+0.650y	100	0.532	<.001	603.2	38.5	322.1	31.6
	Johnstone St.	1963	0.2	y=158.450+0.245x	x=465.994+0.391y	50	0.308	<.05	583.9	29.0	301.5	29.0
			0.3	y=223.807+0.179x	x=547.739+0.209y	50	0.192	NS	617.6	29.7	334.4	27.5
			0.2 & 0.3	y= 77.530+0.400x	x=441.518+0.501y	100	0.447	<.001	600.7	34.0	317.8	30.4

[1] P is the significance level for r.

Table 8. The correlation coefficient (r) and line of best fit describing the relationship between fish length and number of circuli for chum salmon of different ages from one brood year and two locations.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length: P[1]	Hypural length: (mm) $\bar{x}$	Hypural length: SD	Number circuli: $\bar{x}$	Number circuli: SD
Number circuli (y) and fish length (x)	Bella Coola	1963	0.2	y= 37.558+0.061x	x=391.853+2.680y	50	0.407	<.01	588.7	38.8	75.4	5.4
			0.3	y= 18.480+0.104x	x=281.026+4.086y	50	0.654	<.001	620.0	36.7	82.9	5.9
			0.2 & 0.3	y= 8.158+0.116x	x=351.172+3.226y	100	0.612	<.001	603.2	38.5	78.1	7.3
	Johnstone St.	1963	0.2	y= 25.246+0.081x	x=410.075+2.396y	50	0.440	<.01	583.9	29.0	72.5	5.3
			0.3	y= 70.178+0.024x	x=561.775+0.657y	50	0.126	NS	617.6	29.7	85.0	5.7
			0.2 & 0.3	y= 0.673+0.130x	x=430.450+2.162y	100	0.531	<.001	600.7	34.0	78.8	8.3

[1]P is the significance level for r.

Table 9. Analyses of variance, testing for differences in the slopes and elevation of regression lines of length-radius relationship, length-circulus relationship for 1963 brood year of chum salmon (age 0.2, 1966; -0.3, 1967) from the Bella Coola and Johnstone Strait areas.

		Sum of squares	d.f.	Mean squares	F ratio
Length-radius	Slope=0	46,137.70	1	46,137.70	63.274 xxxx
	Slopes equal	31.17	1	31.17	0.042 ns
	Elevations equal	424.23	1	424.23	0.581 ns
	Residual	142,917.79	196	729.17	
Length-circuli	Slope=0	4,097.40	1	4,097.40	97.388 xxxx
	Slopes equal	11.79	1	11.79	0.280 ns
	Elevations equal	43.38	1	43.38	1.031 ns
	Residual	8,246.22	196	42.07	

xxxx=significant at 0.5% level; ns=not significant at 5% level.

Table 10. The correlation coefficient (r) and line of best fit describing the relationship between fish length and scale radius for chinook salmon of different ages from one brood year.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	P[1]	Hypural length (mm): $\bar{x}$	Hypural length (mm): SD	Scale radius (mm): $\bar{x}$	Scale radius (mm): SD
Scale radius (y) and fish length (x)	B.C. Fishery	1963	0.2	y=106.406+0.403x	x=169.299+1.142y	100	0.678		538.8	60.3	323.5	35.8
			0.3	y=149.225+0.389x	x=270.976+0.942y	100	0.606		653.8	56.2	402.6	39.4
			0.2 & 0.3	y= 30.168+0.552x	x=117.093+1.333y	100	0.857		595.4	84.7	358.8	54.5

[1]P is the significance level for r.

Table 11. The correlation coefficient (r) and line of best fit describing the relationship between fish length and number of circuli for chinook salmon of different ages.

Relationship	Location	Brood Year	Age	Line of best fit: Predict y from x	Line of best fit: Predict x from y	n	r	Hypural length: P[1]	Hypural length: (mm) $\bar{x}$	Hypural length: SD	Number circuli: $\bar{x}$	Number circuli: SD
Number circuli (y) and fish length (x)	B.C. Fishery	1963	0.2	y= 48.043+0.062x	x=143.742+4.847y	100	0.548		538.8	60.3	81.4	6.8
			0.3	y= 49.068+0.080x	x=241.306+4.069y	100	0.571		653.8	56.2	101.4	7.9
			0.2 & 0.3	y= 21.164+0.118x	x=107.391+5.338y	100	0.794		595.4	84.7	91.4	12.6

[1]P is the significance level for r.